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Assessment of Green Infrastructure Components and its Environmental Aesthetics Importance's in Lagos State, Nigeria

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Abstract: The study assessed the types and distribution index of green infrastructure components in Lagos State, Nigeria. It employed a descriptive cross-sectional survey design and developed a well-structured questionnaire. GPS and laser measuring devices were used for data collection. Data were obtained from 1,500 respondents divided into three groups using stratified sampling techniques in the study area (LDRA 1=281; MDRA II=563; HDRA III=656) and analyzed using simple percentages, principal components analysis, and regression analyses. The findings revealed that external greenery (24.99%), external/internal planter (19.43%), housing with trees/grass (15.35%), and open space greenery (12.33%) were the principal dimensions or perceived components of green infrastructure in the area. Across the residential-density areas, the study found green spaces to occupy <10 to 25 square meters, with more land area allotted for greenery in the low-residential density area, while 85.3% of the housing units occupied land areas of 100 to 700 square meters. Housing land area was observed to exert a significant influence on the area coverage of the green component ($t = 16.917$, $p<0.05$), implying that the area coverage of the green component increased with the increase in housing land area. The study revealed that a green area of 15 to 30 square meters accounted for the majority of the green components in the study. Therefore, it proposed an area of 22.5 square meters as being ideal for green area in all housing land areas due to the clustering of houses within this dimension.

1. Introduction

Green infrastructures are often considered for their aesthetics and recreational attributes. However, due to their ambiguity, decision-makers and practitioners still strive to understand their true advantages and the best practices for local-level management and implementation (Campagna *et al.*, 2020; Llausas and Roe, 2012). Environmental aesthetics, as defined by Nathan and Robert (1999), refers to the relationship between the environment and individuals in terms of sensory experiences, including the physical environment and captivating objects, as well as the physiological and psychological processes of human perception. The concept of environmental aesthetics originates from the pursuit of aesthetic appreciation of natural environments (Brady, 2003). In the twentieth century, there was a renewed interest in the aesthetics of the natural world, leading to the emergence of environmental aesthetics (Brady, 2009). A focal point of environmental aesthetics is the understanding of nature and natural environments (Carlson, 2001). Cheng (2013) argues for eco-aesthetics, emphasizing the importance of ecological awareness in shaping human aesthetic experiences and activities. Some Western aestheticians align with the idea of appreciating both human and natural environments aesthetically, coupled with an ethical commitment to ecological health (Rolston, 2002; Brady, 2009; Carlson and Lintott, 2007; Parsons, 2008; Lintott and Carlson, 2014).

However, several environmental philosophers and aestheticians find the notion of positive aesthetics problematic, as it may undermine the necessity of comparative estimation, which is essential for environmental preservation and planning (Godlovitch, 1998). Additionally, some argue that the concept itself appears conceptual (Stecker, 2012). Notably, green infrastructure is capable of addressing a wide range of economic, environmental, and social challenges through strategic spatial planning by providing ecosystem services (Wilker *et al.*, 2016; Meerow and Newell, 2017). These challenges include wildlife habitat protection, increased recreation opportunities, air pollution mitigation, social inclusion, climate change mitigation, and adaptation (Campagna *et al.*, 2020; Kim and Tran, 2018; Bolund and Hunhammar, 1999). Hence, green infrastructure (GI) has broad applicability for improving the quality of life, not only in urban areas but in all regions (Wilker et al., 2016). Due to its multi-sectorial nature, GI is designed to be a holistic and systematic spatial planning methodology. It also represents a result-oriented and cross-sectional approach that can be substantiated through strategic actions aimed at affirming, rejuvenating, and connecting existing attributes while generating contemporary ones (Campagna *et al.*, 2020; Slalino *et al.*, 2019).

However, it's important to note that there is still no universal consensus regarding GI implementation and design (Campagna *et al.*, 2020). Therefore, GI has emerged as a concept closely associated with and embedded within the framework of nature-based solutions. It offers an integrated and valuable approach for transitioning to a comprehensive, flexible, and sustainable urban environment (Lovell and Taylor, 2013; Masnavi *et al.*, 2019). Although stirring beyond traditional green spaces, which are good for urban aesthetics and public health, GI is debated more as a cost-effective solution to realign urban areas toward long-drawn-out sustainability and resilience (McDonnell and Macgregor, 2016; Wang et al., 2018). As a consistently emanating concept, GI is basically distinguished as a strategically schemed clique of semi-natural and natural areas with other environmental criterion blueprint and oversight to catalyze and delegate a widespread of ecosystem services underneath the converse of sustainability (Romero-Lankao *et al.*, 2016; Zuniga-Teran *et al.*, 2020). Green infrastructure has been studied from the viewpoint of its advantages, and why its possible estimate has not been thoroughly scrutinized at the planning level (Kim and Tran, 2018). Hence, scholars have also purported a set of distinctive green infrastructure planning principles. In the context of the green surge project, Hansen et al. (2017) and Pauleit et al. (2019) reported four pivotal principles that should be integrated into GI planning; such as ecological network and connectivity, social inclusion, green-gray integration, and multi-functionality. Consequently, Roe and Mell (2013) purport a set of principles, including a long-term approach, the importance of scale, and an evidence-based approach. Gradinaru and Hersperger (2019) summarize six principles and conduct an appraisal to understand how one of these principles of GI planning is applied in a strategic map for urban regions in Europe. Kim and Tran (2018) also conduct an assessment of local goals for sustainable green infrastructure. However, their case study is centered on the United States alone, with a focus on storm water management principles. In this context, Green Infrastructure (GI) revolves around the concept's development and implementation, emphasizing the research enthusiasm of specific zones. This study aims to systematically demonstrate the evolution and implications of GI from a long-term perspective, providing a strategic analysis of green infrastructure contributing to the environmental aesthetics of Lagos metropolis. The study's objective includes planning elements, components, performance indicators, and the implementation of green spaces and infrastructure in urban areas. This paper seeks to identify challenges and explore ideas related to green infrastructure planning and implementation, laying the foundation for future regional policies in Lagos metropolis, Nigeria.

2. Materials and methods

2.1 Study area and sample site

The study was carried out within Lagos Metropolis, Nigeria, around longitudes 3°249'E and latitudes 6°279'N, with a coastline of approximately 180 km (Odunuga *et al.*, 2012). The state has a total land area of 3,577.28 km², of which 22 percent is wetland, and a population density of approximately 5,926 persons per km² (Oshodi, 2013). Lagos state's population was estimated to be 24.5 million in 2015 and 29 million by 2020 (Lagos Water Corporation, 2011), with a growth rate of 3.2 and 8 percent, respectively (World Bank, 2013). The state's geology consists of coastal plain sands and a tidal flat with alluvium (BRNCC, 2012), while the vegetation is a tropical rainforest zone, consisting of mangrove swamps, freshwater swamps, lagoons, and creeks. There are two distinct climatic conditions in the state: dry and rainy. **Figure 1** presents the map of green infrastructure distribution of the study area, while **Figure 2** shows the research flowchart employed in the study.

2.2 Study Design and Research Approach

The study employed a research approach that incorporated both primary and secondary data. The primary data were gathered through a field survey of the slum settlement. On the other hand, secondary data were derived from relevant literature sources, such as journals and books, as well as from land use maps of the study area, documents from community and government agencies, and internet materials.

2.3 Sample Location

The target population of the study comprised property owners, users, and occupants who were selected across three (3) residential areas in metropolitan Lagos. Sixteen (16) out of the twenty (20) LGAs in Lagos State constituted the sampling sites (Metropolitan Lagos), which formed 60% of the whole sampling frame. According to the National Population Commission (NPC) in 2006, Lagos had a population of 9,113,605 and 2,497,419 households. It is estimated that the 16 LGAs have 8,048,430 people and 15,532 households.

2.4 Survey

The sampling procedure for selecting the study area is a multi-stage type of sampling. It involves dividing the population (metropolitan Lagos) into groups based on residential density (low, medium, and high). A descriptive survey design was chosen due to the unique characteristics of the inhabitants, that enables development of a detailed understanding of the study area. Additionally, reconnaissance inspection of the study area was also conducted. The selection of houses followed a systematic sampling method. Random selection for the first house was used, and subsequent houses were chosen at intervals of every fifth house. Simple random sampling was employed to select a household head, and in cases where the household head was unavailable, the wife or a mature child was selected.

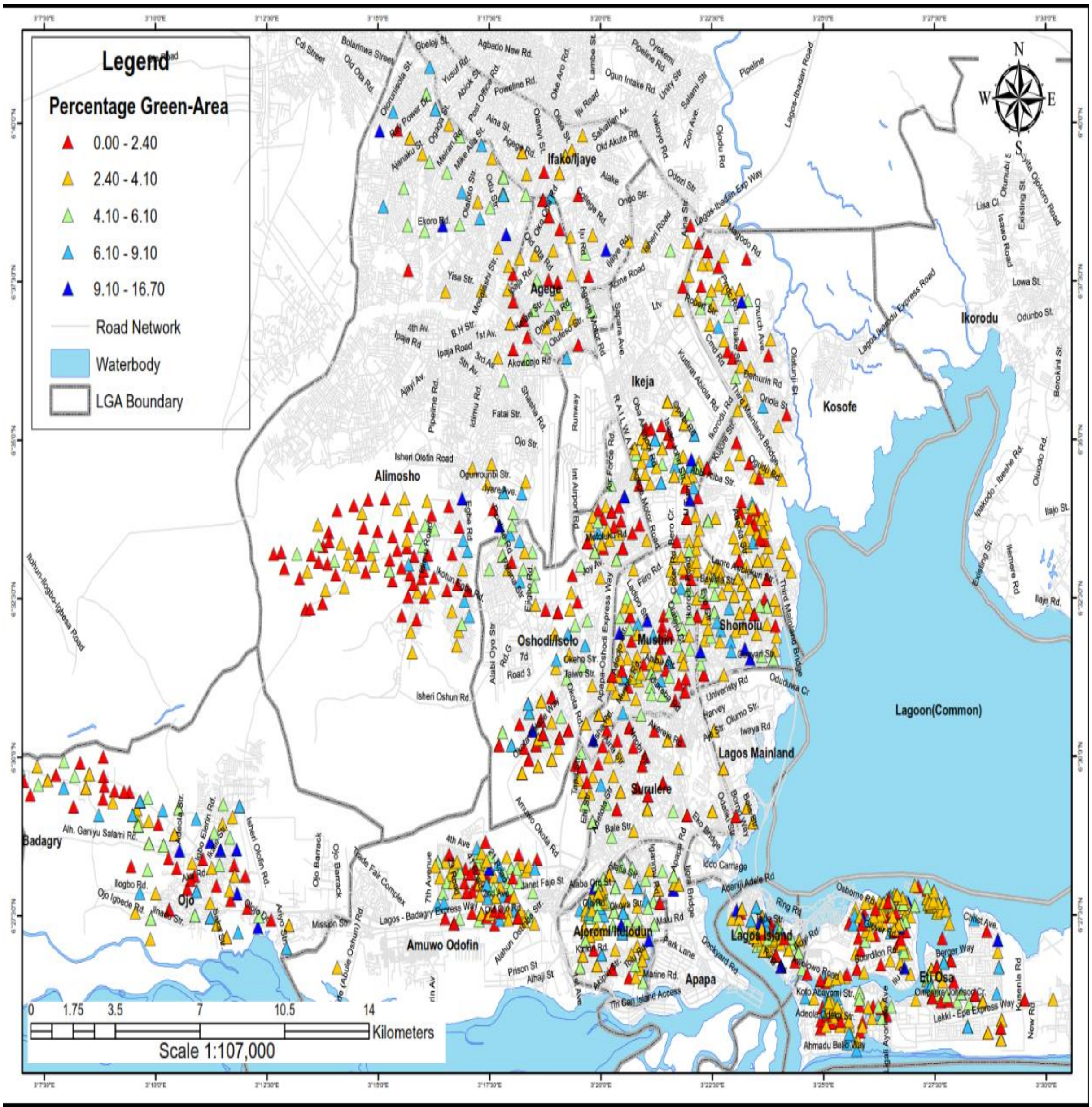

Figure 1. Map of green Infrastructure distribution in Lagos Metropolitan area

2.5 Questionnaire

Pre-testing of the questionnaire was performed to ensure validity and reliability. The pilot survey was conducted in early September 2020. Consequently, Greeneries in low and medium residential areas were observed. Twelve neighborhoods were selected in the Low-Residential-Density Areas (LRD-12), twenty-four neighborhoods in the Medium-Residential-Density Areas (MRD-24), and twenty-eight neighborhoods in the High-Residential-Density Areas (HRD-28) **(Table 1).** A comprehensive house list was prepared to identify the actual houses for sampling. Notably, Van Teijlingen et al. (2001) provided useful information about the study's resource management processes and scientific evidence through the pilot survey. Hill (1998) suggested using 10 to 30 participants for survey research piloting. In this study, 10 to 40 participants was used based on the formula stipulated by Berenson et al. (2006);

$$n = \frac{Z^2 \ X \ S^2}{D^2} \qquad \textbf{Eqn. 1}$$

Where n = minimum sample size; z = value of the distribution function; s = population standard deviation while d = acceptable standard error of the mean.

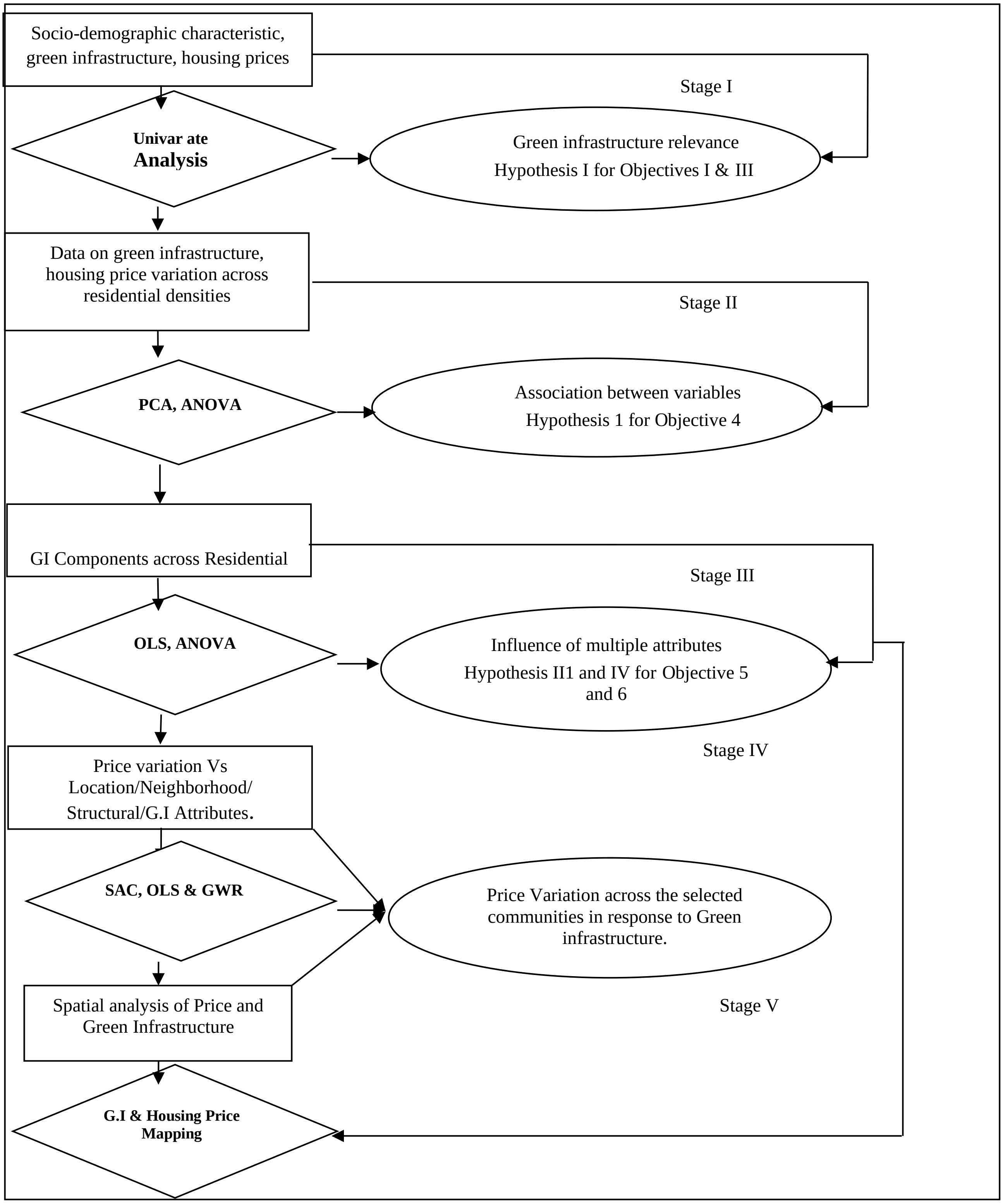

Figure 2. Analytical design flow chart of the study
Source: Author's field survey, 2021.

Furthermore, trained interviewers visited more than 2,000 houses, and the administration of the questionnaire began with every second house on every chosen street in the neighborhood. However, the total number of questionnaires administered in each LGA was proportional to the number of neighborhoods chosen in a ratio of 3:6:7 (LRD 1=281; MRD II=563; HRD III=656). The study also adopted the same procedure, with sample sizes of 48, 495, and 675 for low, medium, and high residential density areas. Notably, this study focused on houses with greenery, resulting in larger sample sizes for low and medium residential density areas compared to Farinmade (2016). The questionnaire was administered to household heads currently occupying a property, either rented or personally owned. One respondent per chosen house was interviewed. No household head under the age of 18 was interviewed, as it was presumed that such underage individuals might be unable to express independent housing preference opinions. Gender was also considered important, as most heads of households are male. However, there are cases where women take charge of housing responsibilities or fill in for male individuals in the housing market. In total, 64 neighborhoods were selected across the three residential areas, with 1,500 households sampled (one respondent per household), representing a response rate of 50%. This was achieved using Equation 2;

$$S = \Psi^{*}(+ \Psi/N^{-1}); Where\ \Psi = (\frac{1.96^{2*}(p^{*}1-p)}{\mho} \qquad \boldsymbol{Eqn. 2}$$

Where

Sample size" =S

Households' population" = N

$\mho$ = precision = 5%

1.96 = t-value at 95%

P = highest expected frequency" = 60%

$I - P$ = worse expected frequency" = 40%

The sixteen (16) Local Government Areas chosen were arranged into three residential density clusters: Low Residential Density (LRD), Medium Residential Density (MRD), and High Residential Density Area (HRD). Since each of these residential density areas contained numerous communities, the study proactively prioritized only communities/estates with evidence or mosaic of green infrastructure, such as trees, shrubs, grasses, flowers, and green walls/fences. This informed the selection of the 64 neighborhoods/political wards across the three residential density zones used for the survey. Copies of the questionnaire were used to elicit information on various issues, including:

i. Perceived role of green infrastructure in house price variation
ii. Predictors of housing cost
iii. Perceived determinants of housing prices
iv. Estimates of housing prices/cost
v. Assessment of housing quality

Notably, residents selected for this survey were those who gave verbal consent to participate after being informed of the study's purpose. However, the survey was conducted for one year (2021), and coordinates were recorded at each sample point using a Garmin GPS receiver (model: GPSMAP 76CSX). **Table 1** shows the sampling locations and population estimations.

Table 1. Questionnaire administration in relation to population distribution across the study area

Study Sampling Units By Wards, LGAS And Neighborhoods								
S/N	CD	Density Type	Lagos LGAs	Lagos Population in 2006	No of H/holds	No of Wards	No of Selected Wards	Selected (64) Ward/Locality
1	I	LDA = 281Q	ETI-OSA	283,791	809	9	6	Ikoyi I, Ikoyi II, V/Island I, I V/Island II, Lekki 1, Ajah.
2	I		IKEJA	317,614	929	10	2	GRA, Onigbongbo
3	I		APAPA	222,986	750	9	4	Apapa I, Apapa II, Apapa III and Apapa IV
4	II	MDA = 563Q	SOMOLU	403,569	967	8	4	Gbagada I, Gbagada II, Akoka, Palmgrove
5	II		AMUWO-ODOFIN	328,975	833	12	4	Festac I, Festac II, Festac III, Satellite Town,
6	II		SURULERE	502,865	975	12	4	Shitta/Ogunade drive, Adeniran Ogunsanyan, Iponri housing Estate
7	II		KOSOFE	682,772	1,275	12	4	Ifako/Gbagada, Anthony/Mende, Ogudu/Ojota, Isheri/Olowo'ra
8	II		IFAKO-IJAIYE	427,737	924	14	4	New Ifako/Oyemekun, Obawole, Ijaiye/Ojokoro
9	II		LAGOS MAINLAND	326,700	1,005	10	4	Alogomeji, Yaba/igbobi, Abuleoja/Oyadiran, Iwaya.
10	III	HDA = 565Q	LAGOS ISLAND	212,700	1,328	18	4	Olowogbowo, Epetedo, OkeFaji, Agarawu/Obadina
11	III		MUSHIN	631,857	981	15	4	Idioro/Odiolowo, Ojuwoye, Idiaraba, Papa Ajao
12	III		OSHODI/ISOLO	629,061	928	11	4	Oshodi/Bolade, Orile/Oshodi, Mafoluku, Ejigbo
13	III		OJO	609,173	767	13	4	Ojo, Okokomaiko, Ajangbadi, Ijanikin
14	III		ALIMOSHO	1,319,571	947	11	4	Egbeda, Ikotun/Ijegun, Igando/Egan, Ayobo
15	III		AJEROMI/IIFELODUN	687,316	980	17	4	Tolu/Ajegunle, Ojo Rd, Awodiora, Olodi,
16	III		AGEGE	461,743	1,134	10	4	Oniwaya/Papaoku, Okekoto, Orile Agege/Oko-oba, Tabontabon/Oko-Oba.
17		Lagos Suburb	BADAGRY	237,731	614	11		
18			EPE	181,734	1,401	18		
19			IKORODU	527,917	1,066	18		
20			IBEJU-LEKKI	117,793	1,054	16		
				9,113,605	**19,667**	**254**		

Source: Authors field survey, 2021

2.6 Green infrastructure index

This research study identifies 16 Green Infrastructure Components (GICs) measured based on the presence of these 16 variables in a housing unit, as shown in Table 1. These variables collectively constitute the green infrastructure components within the study area, encompassing both the neighborhood and housing units. When all sixteen variables are identified within a housing unit, each component is represented as 'Yes' (1), whereas their absence is denoted as 'No' (0). The Green Infrastructure Index is calculated as follows:

$$n = \frac{Number\ of\ identified\ GIC}{Total\ number\ of\ GIC} \times 100 \qquad \boldsymbol{Eqn. 3}$$

In this research, two key terms are defined as follows:

i. Number of Identified GIC: This represents the sum of all identified Green Infrastructure Components (GIC) in a building, which ranges from 1 to 16.

ii. Total Number of GIC: This is fixed at 16, representing all the variables identified in this study as green infrastructure components.

Additionally, Green Infrastructure Distribution refers to the size of land occupied by greenery in each housing unit. To calculate the average of this distribution, the mean value for each density within the entire study area was computed. Percentage green area for each housing unit is determined by dividing the measured land area by the measured green area and multiplying by 100. Therefore, the mean of the Percentage Green Area (PGA) for each density area represents the average percentage of green area in that density area, while the overall mean of the PGA represents the average PGA for the entire study area.

2.7 Statistical analysis

The data obtained were subjected to descriptive analyses (frequency, percentage, and charts) and inferential statistics (analysis of variance, regression analysis, principal component analysis) using the social sciences statistical package (SPSS version 20.1).

3. Results and Discussion

3.1 Demographic and socioeconomic characteristics

The results in **Table 2** show that males slightly dominated the survey. This is because 50.4% of the respondents surveyed across the selected residential areas were males, while 49.6% were females. Although there were more males in low (57.0%) and medium (50.3%) residential densities, females showed a higher percentage of 52.6% in high residential areas. However, a similar pattern of male dominance was observed in the respective residential areas.

Information on the age of respondents, presented in **Table 2** and **Figure 3**, revealed that the majority (75.6%) of the residents/users/owners of green infrastructure fall within the ages of 18 to 60 years. The 41-50 years age bracket is dominant in low (38.1%) and medium (31.3%) density areas, while 31.5% of the residents in the high-density areas were between 31-40 years. As shown in **Figure 3**, a normal distribution in the age pattern is evident across the three residential densities. The educational status revealed that the majority of the respondents, precisely 87.7%, have post-primary education (**Table 2**). However, the results reveal high literacy, which, to a greater extent, influences stakeholders' perception of green infrastructure, its components, and how housing prices are influenced by the category of green infrastructure. The results further reveal that educated individuals were involved in green infrastructure and housing business. A similar high literacy level of over 94% was reported in Lagos State by Dipeolu et al. (2021).

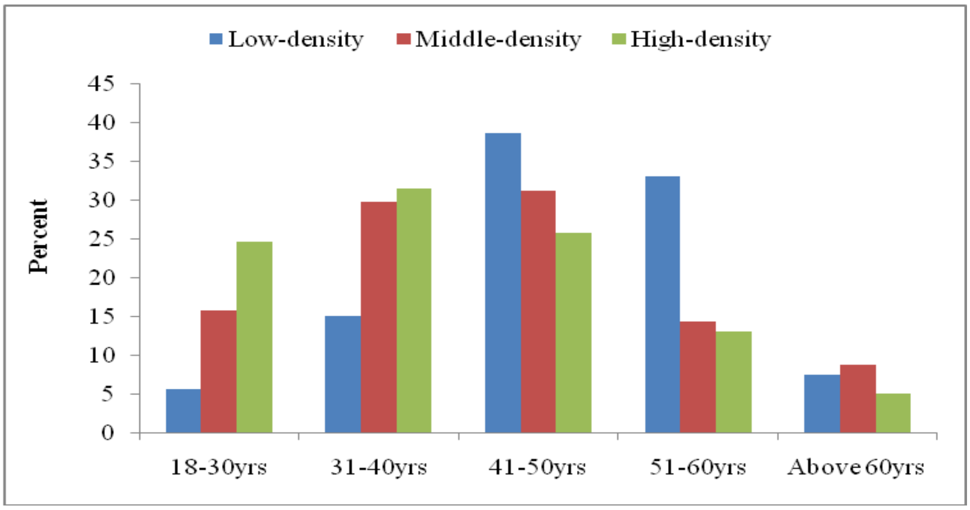

Figure 3. Age of respondents across residential density areas

Table 2. Socio- demographic profile of respondents

Variables	Categories	Residential densities Low (%)	Medium (%)	High (%)	Total %
GEN	Male	57.0	50.3	47.4	50.4
	Female	43.0	49.7	52.6	49.6
AGE	18-30yrs	5.6	15.7	24.6	17.7
	31-40yrs	15.1	29.8	31.5	27.4
	41-50yrs	38.7	31.3	25.8	30.4
	51-60yrs	33.1	14.3	13.1	17.8
	Above 60yrs	7.5	8.8	5.0	6.8
EDU	No Formal Education	4.9	5.5	8.8	6.9
	Primary Education	1.3	2.0	9.6	5.4
	Secondary Education	9.5	26.5	40.7	29.4
	Tertiary Education	82.6	63.6	37.2	55.4
	Others	1.6	2.4	3.6	2.8
OCCU	Private Worker	30.8	22.3	29.8	27.6
	Public Worker	24.9	24.1	9.1	17.3
	Small Scale Entrepreneur	18.4	20.1	24.3	21.7
	Unemployed/Retiree	8.5	11.3	14.7	12.3
	Self Employed	17.4	22.3	22.0	21.1
INC	Below N100,000	13.8	29.4	55.8	38.3
	N100,000-N200,000	16.4	39.7	34.7	32.3
	N201,000-N300,000	12.1	13.5	7.1	10.2
	N301,000-N400,000	9.5	4.9	1.5	4.3
	N401,000-N500,000	24.6	7.7	0.6	8.1
	Above N500,000	23.6	4.9	0.3	6.8
REL	Christianity	62.0	65.3	58.5	61.4
	Islam	37.4	34.2	41.3	38.2
	Traditionalist/pagans	0.7	0.4	0.2	0.4

On occupation, the study revealed that green infrastructural components are explored and utilized by people across different occupations, with a high proportion among those in private occupation, self-employed, and small-scale entrepreneur businesses. The income of respondents revealed that stakeholders involved in green infrastructure earned different amounts of income, with a good proportion (80.8%) earning <₦100,000 - ₦300,000 monthly, suggesting that the stakeholders are, to a large extent, middle-income earners (**Table 2**). The implication is that the income of the stakeholders is a determinant of the type of green infrastructure housing to buy, rent, purchase, and build. Religiously, the majority of the respondents (61.4%) were Christians, while 38.2% were Muslim, and only 0.4% were traditionalist or pagans. This implies that both Christians and Muslims make use of green infrastructure housing.

3.2 Green infrastructure types and distribution

The results in **Table 3** provide vital information about the types of green infrastructures common across the residential-density areas considered in this study. A total of 16 variables were identified as green components, both in housing and neighborhoods. Based on the mean values, the study identified green roofs, botanical gardens, and green playgrounds as the most widespread neighborhood components of green infrastructures across residential-density areas. These green infrastructure components can be considered very common in these areas. In many of the houses, particularly in low and medium-residential areas, greenery can be seen on rooftops, walls, and around the compounds. This not only enhances the aesthetic value of the housing units but also contributes to the beautification of the entire area.

Table 3. Mean attributes of neighborhood components of green infrastructure

GI components	Residential densities			Overall mean values
	Low	Medium	High	
Neighborhood greenery	1.17	1.33	1.66	1.45
Private garden	1.36	1.86	1.97	1.80
Ornamental tree	1.36	1.89	1.99	1.82
Pocket planter	1.50	1.93	2.00	1.87
Housing with trees grass	1.31	1.46	1.78	1.57
Green roof	1.22	1.53	1.85	1.61
Neighborhood with potted flowers	1.38	1.69	1.97	1.75
Grass/flowers	1.89	1.97	1.99	1.96
Green playground	1.77	1.89	1.98	1.91
Walkways with green components	1.77	1.70	1.95	1.83
Botanical garden	1.81	1.88	1.99	1.92
Housing greenery	1.18	1.36	1.74	1.50
Housing trees	1.42	1.51	1.85	1.65
Housing grass	1.24	1.60	1.94	1.68
Housing flowers	1.23	1.48	1.92	1.63
Housing potted flowers	1.21	1.52	1.92	1.64

These findings align with those of Dipeolu and Ibem (2020), who classified green features such as green roofs, parks, gardens, lawns, sports fields, and green corridors as common green components in Lagos Metropolis. Other prevalent green infrastructures in the neighborhood or residential-density areas include pocket planters, walkways surrounded by green components, ornamental trees, and private gardens. These results are consistent with the findings of Gill et al. (2008), who suggested that local land use and coverage are direct drivers of ecosystem service change in the urbanization process. Furthermore, they complement the diversity and matrix of green infrastructural components in the study area. These identified greenery elements are indeed common and easily visible in the study area, constituting a significant percentage of green components in both the neighborhood and housing.

3.3 Grouping of green infrastructure distribution

Principal components analysis (PCA) was employed to identify the principal components of green infrastructure in the area. This statistical technique was chosen due to the number of variables used to measure the green infrastructural components. The results obtained showed that PCA, applied to 16 variables, resulted in the extraction of four components that accounted for 72.1% of the variation in the dataset (**Table 4**). Using component loadings of ±≥0.8 as the criteria for selecting variables, Principal Component One (PC1) exhibited a strong and positive loading on the variable 'use of housing greenery' (0.839). PC1 was responsible for 24.99% of the total variance in the perceived set of data related to the components of green infrastructure, and the positive loadings of the variable indicated an increase in housing greenery. Consequently, the variable loaded on PC1 represented external greenery. PC2 had two variables that loaded positively on it: ornamental tree (0.884) and pocket planter (0.844). PC2 was responsible for 19.43% of the total variance in the variable set, and positive loadings represented an increase in ornamental tree and pocket planter in the study area. PC2 represented internal/external greenery. PC3 was accountable for 15.35% of the total variance in the perceived set of data and had only one variable that loaded on it: housing with trees/grass (0.806). The positive loading of the variable indicated an increase in housing with trees/grass. Based on the nature of the variable that loaded in PC3, it could be said to represent housing with trees/grass. PC4 was responsible for 12.33% of the total variance in the set of data and had only one variable that loaded on it: walkways surrounded with green components (0.853). PC4 symbolized open space greenery.

The results presented in **Table 4**, therefore, identify external greenery, external/internal planter, housing with trees/grass, and open space greenery as the principal dimensions or perceived components of green infrastructure in the area. These green infrastructural components represent over 70% of the green infrastructural components found in the area. It can be seen that green infrastructure has its own research emphasis in different disciplinary areas and has different understandings of the concept of green infrastructure (Zhang and Chui, 2019). Hence, the identified components of green infrastructure in the present study fall within Dipeolu and Ibem (2020) classification of green infrastructure in urban areas. In a related study, Dipeolu and Ibem (2020) stated that green infrastructural components in urban areas are in four different forms: (1) green features like green roofs, parks and gardens, lawns and sports fields, green corridors; (2) tree features like urban woodlands, street trees; (3) water features like wetland, rivers, ponds, lakes and fountains; and (4) others like open spaces, non-green parks, wildlife habitats, school play fields, cemeteries. These four components, to a large extent, portray the picture of green infrastructural components in the area, demonstrating that they are the common ecological components in the area.

The first extracted component shows external greenery as the most common green infrastructural component in the area. External greenery is found in many of the houses in the study area, mostly in the low and medium-residential density areas (**Table 4**). This is apparent, as a look at the response rates on the existence of external greenery showed they are found in high numbers in the low and medium-residential density areas with response rates of 82.3% and 64.5%, respectively, while the high-residential density area has a response rate of 25.5%. The responses imply that external greenery is most favored and exists in the low-residential density area. Housing greenery is characterized by a mix of green components such as trees, grasses, and flowers. One of the obvious external greenery components is houseplants (with different types of trees and flowers) usually found inside and outside residential areas. These findings reaffirm that green infrastructure projects have extensive themes and spatial scales, and they share the common goal of realizing sustainable land management planning (Bowler *et al.*, 2010; Mdehheb *et al.*, 2020).

The second extracted component is external/internal greenery. External/internal greeneries like ornamental tree/pocket planters are found on windows and walls as well as fences in residential areas. Many of the pocket planters are constructed using polythene bags and others are constructed using cements for the sole purpose of growing green components. Pocket planters as shown by the response rates are in high numbers in the low-residential density areas (50.5%) and very low in the high-residential density area (0.3%) (**Table 4**). They can either be indoor plant walls or outdoor living walls with different green components mostly flowers. The third extracted component is housing with trees/grass; which indeed is easily seen in many houses in the area. In many of the houses, grass mostly lawns are maintained to beautify the environment, while in others both trees and lawns are grown giving it an ecological mix. The response rate shows that this green component is found in the three areas with high presence in the low-residential density area (69.2%) and low in the high-residential density area (22.5%). In addition, open space greenery is the fourth extracted component of green infrastructure in the area. This is another common green infrastructural component in many residential areas and along walkways.

Table 4. PCA results showing grouping of green infrastructures distribution

Variables	**Principal components**			
	PC1(External Greenery)	**PC2 (Internal Greenery)**	**PC3(Neighborhood Greenery)**	**PC4 (Open Space G..)**
Housing greenery	0.839	0.103	0.242	0.125
Housing trees	0.797	-0.037	0.110	0.221
Housing potted flowers	0.786	0.331	0.177	0.171
Housing flowers	0.759	0.332	0.255	0.204
Housing grass	0.756	0.382	0.227	0.219
Neighborhood with potted flowers	0.570	0.399	0.424	0.082
Ornamental tree	0.171	0.884	0.183	0.121
Pocket planter	0.173	0.844	0.209	-0.030
Private garden	0.245	0.799	0.135	0.228
Housing with trees/grass	0.278	0.166	0.806	0.025
Neighbour greenery	0.314	0.237	0.752	0.261
Grass flowers	0.370	0.354	0.674	0.118
Botanical garden	0.272	0.044	0.017	0.853
Walkways surrounded with green components	0.088	-0.110	0.421	0.710
Green playground	0.153	0.312	0.102	0.599
Green roof	0.180	0.346	-0.348	0.449
Eigenvalues	**4**	**3.11**	**2.46**	**1.97**
% variance	**24.99**	**19.43**	**15.35**	**12.33**
Cumulative exp.	**24.99**	**44.42**	**59.77**	**72.09**

[a]the underlined with coefficients ±≥0.8 are significant

In some houses, open space greeneries are constructed and designed with green components. This helps to beautify the environment and to mimic the forest. Again, though the presence of walkways with green components is not widespread in the area, but it is commonly found in medium-residential density area (30.2%) followed by the low-residential density area (23.3%) (**Table 4**). The result in Table 4 therefore shows the preference of respondents to the types of green infrastructural components in the area. This result is consistent with the findings of Dipeolu et al. (2021) in Lagos State where they found that majority of the residents' preferred urban green infrastructure (UGI) with green features than all the other forms of UGI. These results corroborate with Pataki et al. (2011) who conducted a detailed analysis and found that the costs and benefits and services and hazards of an ecosystem should be weighted in green infrastructure construction. Therefore, the results in **Table 4** recognizes external greenery, external/internal planter, housing with trees/grass and open space greenery as the main dimensions or perceived components of green infrastructure in the area.

3.4 Distribution of green infrastructure index

The sixteen variables in **Table 5**, which make up the green infrastructure components of the study area (both neighborhood and housing), represent the mean of the percentage green area (PGA) for each density area. This average percentage green area in each density area contributes to the overall mean of the PGA, which represents the average PGA of the study area. As presented in **Table 6**, the average area coverage of Green Infrastructure in all the sampled residences in Lagos State across all three densities is 18.8m². This indicates that 3.9% of the entire land area is covered with greenery, resulting in a green infrastructure index of 0.23.

Furthermore, the results show that the average area coverage of green infrastructure in the medium-density area is 19.1m², which is greater than the ACGI of the High-Density Area (**Table 5**). This suggests that 3.39% of the entire area sampled in the medium-density area is covered with greenery. However, it was also revealed that the Medium Residential Area has a larger area covered by greenery (19.1m²) compared to the High-Density Area (14.4m²) in the study area. This accounts for 4.1% of the total land area in the medium-density area and results in a green infrastructure index of 0.5. It therefore revealed that the percentage of green area in the medium-density area is lower than that in the high-density area, thus difference is a function of the land area occupied by the housing units.

Lastly, the results show that the average green infrastructure coverage in the low-density area of the study is 27.9%, indicating that 4.0% of the entire land area sampled in the low-density area is occupied by greenery, with a green infrastructure index of 0.62 (**Table 5**). It's important to note that the Green Infrastructure Index does not account for the percentage of residential housing units occupied by greenery. It only provides an overview of the number of green components present in the three residential density areas.

Table 5. Green infrastructure index

Location	Average Area Coverage of Green Infrastructure (m^2)	Percentage Green Area (%)	Green Infrastructure Index
High Density Area	14.4	4.1	0.23
Medium Density Area	19.1	3.4	0.47
Low Density Area	27.9	4.0	0.62
Lagos Metropolis	18.8	3.9	0.4

For instance, the low residential density area, with an index of 0.62, indicates more components of green infrastructure compared to the high residential density area, which has an index of 0.23 (primarily trees and grass). Therefore, to establish the influence of green infrastructure on housing prices, it is crucial to consider the amount of space occupied by greenery when making recommendations regarding the allocation of housing units to greenery. The findings from this study reaffirm that green infrastructure consists of multiple components, such as Family Garden (Cameron et al., 2012) and Greenway (Newell et al., 2013).

3.5 Variation of green infrastructure index

The results in **Table 6** are used to demonstrate the variation in the GI Index across the three residential density areas. It reveals significant differences in the distribution of percentage green area (F=13.960, $p < 0.05$), Green Area (F=167.019, $p < 0.05$), and green infrastructure index (F=285.287, $p < 0.05$).

Table 6. ANOVA result of green infrastructure Index

Variable	Source of variation	Df	F	Sig.
Percentage Green Area	Between Groups	2	13.690	0.000
	Within Groups	1413		
	Total	1415		
Green Area	Between Groups	2	167.019	0.000
	Within Groups	1411		
	Total	1413		
Green Infrastructure Index	Between Groups	2	285.287	0.000
	Within Groups	888		
	Total	890		

*Significant at 5% alpha level.

3.6 Area coverage of green infrastructure

Table 7 shows the approximate area coverage of green infrastructure across the study locations, as well as the land area occupied by housing units. The results revealed that across the residential-density areas, green infrastructures covered 10 to 25 square meters, followed by those that occupied less than 10 square meters, while few housing units had above 25 square meters of land occupied or covered with green infrastructures (**Figure 4**). A further look at the respective residential areas revealed that in the low-residential-density area, a good number of the measured green components occupy 10 to 25 square meters, and by extension, 91.8% of the housing units have 10 to above 50 square meters of their land area covered with green infrastructures. In the medium-residential-density area, the majority of the houses have open space green areas of 10 to 25 square meters, and by extension, 94.2% of the housing units have 10 to less than 50 square meters of their land area covered with green infrastructures. A similar pattern was observed in the high-residential-density area. In addition, housing units across the neighborhood have different dimensions, as shown in **Table 7**. The results show that a good number of the housing units have an approximate land area of 501 to 700 square meters, followed by those that occupy 301 to 500 square meters. In summary, **Table 8** demonstrates that green spaces occupy <10 to 25 square meters across the residential-density areas, with more land area allotted for greenery in the low-residential density area. Furthermore, 85.3% of the housing units across the residential-density areas occupy land areas of 100 to 700 square meters.

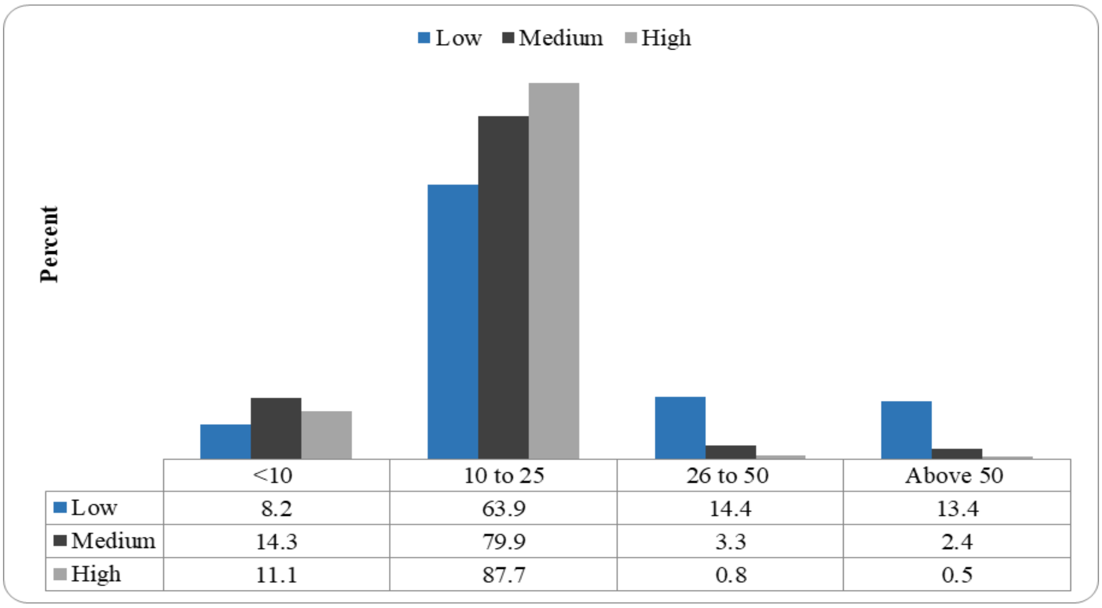

Figure 4. Area coverage (m^2) of green components across residential density areas

Table 7. Area extent occupied by green infrastructure and housing land area

Variables	Categories	Residential densities			Total %
		Low (%)	Medium (%)	High (%)	
Approximate Open Space Green Area (m^2)	<10	8.2	14.3	11.1	11.5
	10 – 25	63.9	79.9	87.7	80.1
	26-50	14.4	3.3	0.8	4.5
	Above 50	13.4	2.4	0.5	3.9
Land area of housing unit(m^2)	100 – 300	1.	3.1	33.3	16.5
	301 – 500	9.6	22.9	34.6	25.6
	501 – 700	59.8	55.1	28	43.2
	701 – 900	22.7	15.9	4.5	12.0
	Above 900	7.2	2.2	0.7	2.7

3.7 Predictor of green area

In this study, the influence of housing land area on the area coverage of the green component was examined. The results obtained are presented in **Table 8**. The results revealed that housing land area significantly explained 16.8% of the variation in the area coverage of the green component. Furthermore, the results indicated that housing land area exerted a significant influence on the area coverage of the green component ($t = 16.917$, $p < 0.05$). The beta weight (β) revealed that an increase in housing land area would result in a 41% increase in the area coverage of the green component. This implies that the area coverage of the green component increases with an increase in housing land area. The results in **Table 8** suggest that housing land area has a considerable influence on the area coverage of the green component. This study reaffirms how green infrastructure is characterized by its multi-functionality, reflecting how it may be used and its capacity for the provisioning of ecosystem services (Badiu et al., 2019). In addition, the association between land area and green area (area coverage of green infrastructure) is further shown in **Figure 5**. The association between land area and green area reveals an increasing trend, implying that the green area (area coverage of green infrastructure) increases with the increase in land area. The R^2 result indicates that land area is responsible for a 16.8%

increase in the area coverage of green infrastructure, while 83.2% of the unexplained variances in the area coverage of green infrastructure are attributed to other parameters, not necessarily land area. This goes to show that land area is not the only principal factor that determines green area.

Table 8. Summary of regression analysis of land area on green area

Predictor Variables	Coefficients		
	b	β	t-value
Land area	0.024	0.410	16.917*
Test results			
F- value	286.178*		
R	0.410		
R^2	0.168	16.8%	
Constant	5.980		

*Significant at 5% significance level

A look at the information and pattern portrayed in **Figure 5** reveals that most of the area coverage of green infrastructures concentrates around land areas greater than 300 square meters. This shows that an increase in land area above 300 square meters brings about a corresponding increase in the area coverage of green infrastructures. It further reveals that green areas of 15 to 30 square meters account for the majority of the green components in the neighborhood.

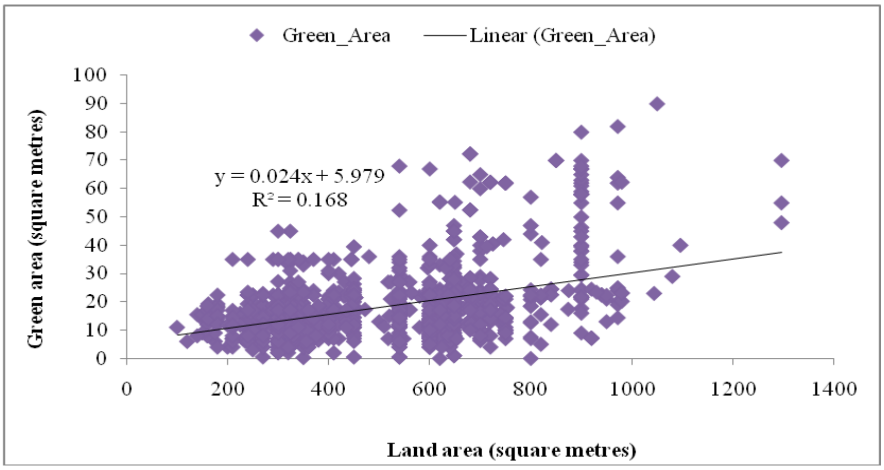

Figure 5. Land area-green area relationship

Conclusion

The study has clearly shown that different components of green infrastructure exist across the low, medium, and high-residential density areas in Lagos State. The distribution of green infrastructure is observed in the study to be high in the low-residential density area and low in the high-residential density area, and this thoughtfully contributes to the observed variation in households' perception of the relevance of green infrastructure to the environment. Green components are observed in the study to be used by people across different religions. It is argued that Christians, Muslims, and traditionalists stay under trees or around green components to observe some solemn or silent moments, and many use them as places for prayers. The study found that across the residential-density areas, green spaces occupy less than 10 to 25 square meters, while 85.3% of the housing units occupy land areas of 100 to

700 square meters. Across the study locations, a significant percentage of the green areas occupy 15 to 30m², with more land made available in the low-residential area. Though housing land area is found to exert a significant influence on the area coverage assigned for green components, the study believes that an area of 22.5m², without any consideration across income groups, is suitable for green infrastructure.

This green area is applicable to developers and landowners across the three residential density areas. Based on the research findings, an area of 22.5m^2 has been proposed or suggested to be legalized by the government for green components in all housing projects. This dimension may be increased depending on the size of the land. Government should, as a matter of necessity, make it compulsory for all infrastructural development in the state, irrespective of the size of the land, to allocate a minimum of 22.5m^2 of the land for green components. The said land area can be distributed around the building project. If this is seriously looked into by the government and made compulsory, it will go a long way in increasing the amounts of green infrastructures in the state. This, in turn, will make the state more habitable and help control environmental disasters like soil erosion. Additionally, the increase in the density of green components will reduce the heat island effects by moderating temperature and reducing the concentration of carbon dioxide in the environment, especially around transport corridors.

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